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Issued March 21, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY—CIRCULAR 209.

A. D. MELVIN, CHIEF OF BUREAU.

THE UTILIZATION OF EXHAUST STEAM FOR HEATING BOILER FEED WATER AND WASH WATER IN MILK PLANTS, CREAMERIES, AND DAIRIES.

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It is believed that there are no classes of plants using steam that offer more varied opportunities for the utilization of the waste heat in the exhaust steam than those employed in the dairying industry. And it appears that very few persons responsible for the economical operation of such plants have given this problem the attention that it justifies. As fuel is one of the greatest items of expense in operating a plant of this character, it is important that as much as possible of the heat in the coal be utilized. Even with the best possible arrangement of apparatus there is utilized only a small portion of the heat in the coal.

THE RELATION OF HEAT TO TEMPERATURE.

In order to assist to a better understanding of the possibilities of a pound of steam, its profitable utilization and effect, the heat contained, etc., let us start with 1 pound of ice at zero temperature, Fahrenheit scale, and study the relation of heat to temperature.

When a solid or a liquid changes its state or condition, as when a solid is converted into a liquid or a liquid into a gas or vapor, the change in each case is accompanied by the absorption of heat. This absorption of heat is what we are accustomed to call "latent heat,"[1]—that is, heat that can not be measured by a thermometer—and in order to transfer a substance from one state to another it is necessary only to supply or extract heat. If, for example, we take 1 pound

[1] Latent heat, or "hidden heat," is the heat which is expended in molecular work in separating the molecules of the substance and can not be measured by a thermometer. Every substance has a latent heat of fusion, required to convert it from a solid to a liquid, and another latent heat of vaporization, required to convert it from a liquid to a gas or vapor.

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of ice at zero, F., and apply heat, the temperature will rise until it has reached 32° F. If we continue the application of heat the ice will begin to melt, and after we have supplied sufficient heat the 1 pound of ice will have changed into water at 32° F. Now, if the application of heat be continued the water will grow warmer, but at a slower rate; it takes about double the amount of heat to raise the water 1° that it does to raise the ice 1°. In other words, the specific heat[1] of water is approximately double that of ice.

When sufficient heat has been added to raise the 1 pound of water to a temperature of 212° F. there is reached another critical point at which further application of heat to the water, under atmospheric pressure, will not increase its temperature but will change it into steam.

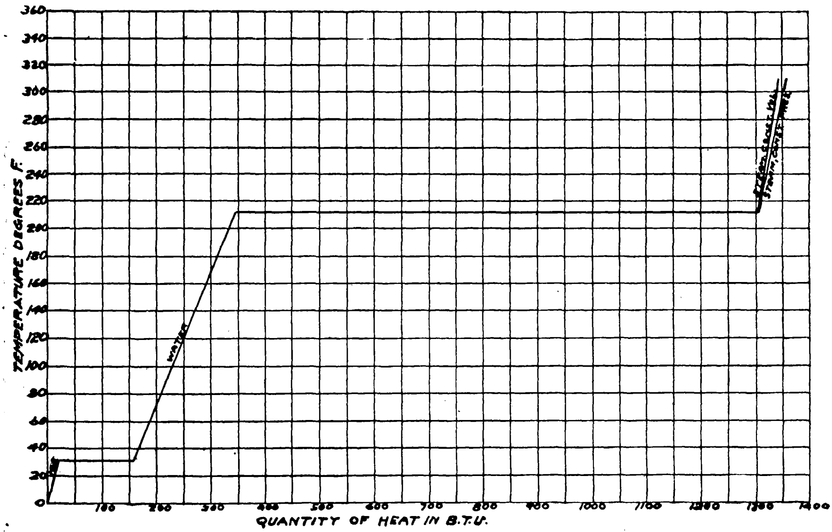

FIG. 1.—Diagram showing the relation of heat to temperature.

It will be noted by referring to figure 1 that to raise the temperature of the 1 pound of ice from zero, F., to the melting point (32° F.) 16 British thermal units[2] are required; in melting the ice, 144 B. t. u.; in raising the temperature of the water to the boiling point, 180 B. t. u.; and to evaporate the water, under atmospheric pressure, 970.4 B. t. u.

The latent heat of fusion and the latent heat of vaporization are represented on the diagram by the two lines which are parallel to the horizontal base line, the length of the lines representing to scale the

[1] The specific heat of a substance is the ability which that substance has to absorb heat compared with that of water. Water being one of the hardest of all substances to heat, its specific heat is taken as unity, consequently the specific heat of other substances is usually less than unity. A better understanding of latent heat and specific heat may be had by studying the diagram, figure 1, which shows graphically the relation of heat to temperature.

[2] A British thermal unit (abbreviated as B. t. u.) is the heat required to raise the temperature of 1 pound of pure water 1° Fahrenheit at or near its maximum density (39.1° F.). For practical purposes, however, it may be considered as the heat required to raise the temperature of 1 pound of water 1° Fahrenheit.

amount of heat expended within the substance in separating its molecules. The rising lines represent the heat required to raise the temperature of the ice, water, and steam, respectively, the latter at constant volume and also at constant pressure.

Steam is merely the vehicle through which the heat of the fuel may be utilized for the purpose of producing mechanical power, heating of buildings, boiler feed water, wash water, etc., and the purpose for which the steam is required determines its pressure. For the conversion into mechanical power, high-pressure steam is usually required, but for heating purposes, steam at approximately atmospheric pressure and a constant temperature of 212° F. is sufficient for most requirements.

THE POSSIBILITIES OF 1 POUND OF STEAM.

To take a more specific case, and one that is considered an average in milk plants, creameries, and dairies, let us consider the possibilities of 1 pound of steam at a gauge pressure of 80 pounds generated from 1 pound of boiler feed water at a temperature of 60° F.

The temperature of the steam at this pressure is 324.1° F., and the 1 pound contains 1,157.4 more British thermal units than did the 1 pound of boiler feed water at 60° F. In order to produce a pound of steam at the above assumed pressure and from boiler feed water at a temperature of 60° F., 266.4 heat units are required to raise the water from 60° to 324.1° F., while 890.9 heat units are consumed in evaporating the water. Suppose this steam is used in an ordinary slide-valve engine such as is commonly used in the type of plant under consideration, using 40 pounds of steam per horsepower hour at a gauge pressure of 80 pounds. Now, as the 1 pound of steam at a gauge pressure of 80 pounds contains 1,157.4 heat units added to feed water at 60° F., the 40 pounds will contain $1,157.4 \times 40 = 46,296$ heat units. Since all the heat not converted into mechanical work nor lost by radiation and leakage is contained in the exhaust steam, it becomes a simple matter to calculate the heat remaining in the exhaust. By referring to the analysis on page 7 of the losses of the plant illustrated in figure 3, it will be noted that the boiler radiation losses are estimated at 8 per cent and the pipe and engine radiation losses are estimated at 2 per cent, making a total loss by radiation of 10 per cent. Since 1 horsepower corresponds to 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour, and since 1 British thermal unit corresponds to 778 foot-pounds, the heat equivalent of 1 horsepower hour is $\frac{1,980,000}{778} = 2,545$ B. t. u. Therefore the heat in the steam converted into mechanical work by the engine is $\frac{2,545}{46,296} \times 100 = 5.5$ per cent. The radiation losses were estimated at 10 per cent, making

a total of 15.5 per cent; and subtracting this from 100 we have 84.5 per cent of the heat in the steam still available in the exhaust.

HEAT LOSSES IN THE AVERAGE SMALL PLANT.

Figure 2 gives a diagrammatic outline of an elementary steam plant with all the accessories that go to make up a complete plant of this character. A great many plants of this type are installed in milk

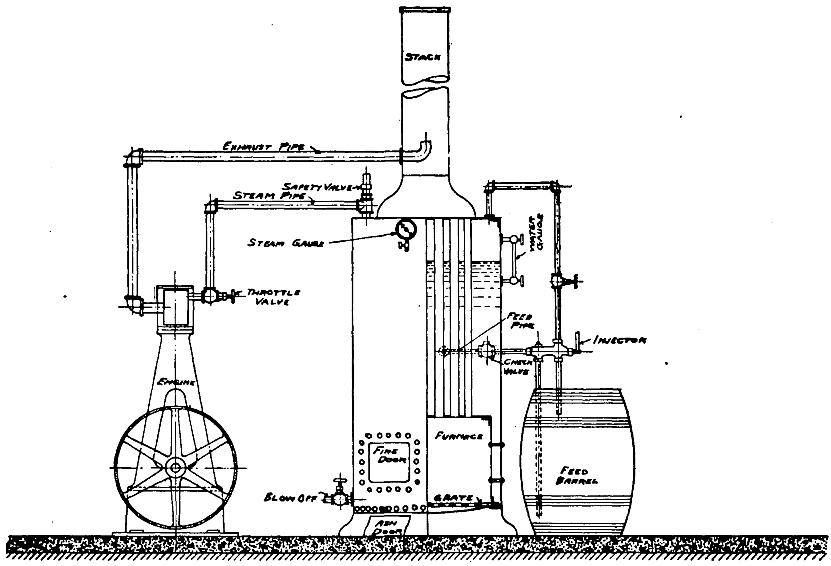

FIG. 2.—Elementary steam plant.

plants, creameries, and dairies, and for this reason an analysis is given of the various losses, which are approximately as follows:

	B. t. u.	Per ct.
Heat value contained in 1 pound of coal	14,000	100
Combined boiler and furnace losses	7,000	50
Heat in the steam	7,000	50
Heat equivalent to 1 horsepower hour	2,545	
Heat required to develop 1 horsepower hour (assuming 50 pounds of steam per horsepower hour, pressure 80 pounds gauge, feed water 60° F.)	57,900	
Percentage of heat in steam realized as useful work..... $\frac{2,545\times100}{57,900}=$	......	4.4
Percentage of heat in coal realized as useful work.. $\frac{2,545\times0.50\times100}{57.900}=$	......	2.2

SAVING IN FUEL THROUGH HEATING THE FEED WATER.

In an elementary steam plant of this character it is the common practice to pipe the exhaust steam into the stack to assist in maintaining a sufficient draft to burn the fuel. A portion of this heat can be

returned to the boiler by heating the feed water and will result in a material decrease in the quantity of fuel required, as is shown by the following figures.

Suppose the steam pressure in a given boiler is 70 pounds by the gauge and the feed water enters the boiler at 60° F., what will be the present gain if the water is heated to 200° F.? The number of heat units required to convert a pound of water at a given temperature into steam at a given pressure is equal to the difference in the total heat of the water and steam. The total heat in 1 pound of water at 60° F. is equal to $60° - 32° = 28$ B. t. u. (32° F. being the freezing point of water).

The total heat in 1 pound of steam at 70 pounds pressure (84.7 pounds absolute[1]) is 1,183 B. t. u. The difference between these two total heats is $1{,}183 - 28 = 1{,}155$ B. t. u. If the water is heated from 60° F. to 200° F. the number of B. t. u. gained by heating is $200 - 60 = 140$. Therefore the gain in per cent would be $\frac{140}{1{,}155} = 0.1212$ or 12.12 per cent.

The maximum gain that can be realized by employing exhaust steam for feed-water heating in an open heater, with a gauge pressure of 70 pounds on the boiler, is approximately 15.2 per cent, this being the case when taking water at an initial temperature of 32° F. and delivering it to the boiler at 212° F.

The following table gives the percentage of saving in fuel by preheating the boiler feed water from various initial temperatures to different final temperatures:

TABLE 1.—*Quantity of fuel saved by heating feed water from various initial temperatures to different final temperatures. Steam pressure 70 pounds gauge (84.7 pounds absolute).*

Initial temperature of feed water.	Temperature to which feed water is heated.														
	100°.	110°.	120°.	130°.	140°.	150°.	160°.	170°.	180°.	190°.	200°.	210°.	220°.	250°.	300°.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
35° F...	5.53	6.38	7.24	8.09	8.95	9.89	10.66	11.52	12.38	13.24	14.09	14.95	15.81	19.40	29.34
40°.....	5.12	5.97	6.84	7.69	8.56	9.42	10.28	11.14	12.00	12.87	13.73	14.59	15.45	18.89	28.78
45°.....	4.71	5.57	6.44	7.30	8.16	9.03	9.90	10.76	11.62	12.49	13.36	14.22	15.09	18.37	28.22
50°.....	4.30	5.16	6.03	6.89	7.76	8.64	9.51	10.38	11.24	12.11	12.98	13.85	14.72	17.87	27.67
55°.....	3.89	4.75	5.63	6.49	7.37	8.24	9.11	9.99	10.85	11.73	12.60	13.48	14.35	17.38	27.12
60°.....	3.47	4.34	5.21	6.08	6.96	7.84	8.72	9.60	10.47	11.34	12.22	13.10	13.98	16.86	26.56
65°.....	3.05	3.92	4.80	5.67	6.56	7.44	8.32	9.20	10.08	10.96	11.84	12.72	13.60	16.35	26.02
70°.....	2.62	3.50	4.38	5.26	6.15	7.03	7.92	8.80	9.68	10.57	11.45	12.34	13.22	15.84	25.47
75°.....	2.19	3.07	3.96	4.84	5.73	6.62	7.51	8.40	9.28	10.17	11.06	11.95	12.84	15.33	24.92
80°.....	1.76	2.65	3.54	4.42	5.32	6.21	7.11	8.00	8.80	9.78	10.67	11.57	12.46	14.81	24.37
85°.....	1.30	2.22	3.11	4.00	4.90	5.80	6.70	7.59	8.48	9.38	10.28	11.18	12.07	14.32	23.82
90°.....	.89	1.78	2.68	3.58	4.48	5.38	6.28	7.18	8.07	8.98	9.88	10.78	11.68	13.82	23.27
95°.....	.45	1.34	2.25	3.15	4.05	4.96	5.86	6.77	7.66	8.57	9.47	10.38	11.29	13.31	22.73
100°....	.00	.90	1.81	2.71	3.62	4.53	5.44	6.35	7.25	8.16	9.07	9.98	10.88	12.80	22.18

[1] Absolute pressure equals gauge pressure plus 14.7 pounds, the pressure of air per square inch at sea level.

For every 10° F. that the feed water is heated before entering the boiler approximately 1 per cent less fuel is required to generate the same amount of steam. Also, for each 10° F. increase in feed-water temperature, the boiler capacity is increased approximately 1 per cent.

Besides the direct saving in fuel due to heating the feed water, the injurious effects of unequal expansion in the boiler caused by feeding water at a low temperature are diminished, and the life of the boiler is prolonged. Furthermore, it is easier to keep a constant pressure on the boiler. There will be a still further gain in the quantity of fuel consumed due to the even firing, for when a fire is crowded to take care of a temporary overload a considerable amount of heat in the coal is lost by admitting an excess of air into the furnace, and by a portion of the combustible matter being carried up the stack unconsumed.

To reduce the percentages of saving in fuel in the foregoing table to their equivalents in dollars and cents, let us assume that the boiler has a capacity of 40 horsepower and that it is operated 8 hours a day, 310 days in the year. With a combined boiler and furnace efficiency of 50 per cent, about 6½ pounds of coal per boiler horsepower hour will be consumed, or 2,080 pounds per day of 8 hours, providing the feed water is admitted to the boiler at 40° F. If the feed water, however, is admitted to the boiler at 200° F., there would be a saving of 13.73 per cent; that is, the quantity of coal consumed per day would be 1,794 pounds. The saving would, therefore, be $2{,}080-1{,}794=286$ pounds per day, or 44.33 tons per year. If the coal cost $4 a ton delivered in the bunkers, the annual saving in fuel would be $\$4\times 44.33=\$177.32$.

The following table gives the annual cash saving of fuel on a 40-horsepower boiler by heating the feed water from various initial temperatures to a final temperature of 200° F.

TABLE 2.—*Amount annually saved by heating feed water to 200° F. from various initial temperatures with coal at stated prices per ton. (Assuming a 40-horsepower boiler working 310 days of 8 hours and 6.5 pounds of coal burned per horsepower hour.)*

Cost of coal per ton (2,000 pounds) in bunker.	Initial temperature of feed water.							
	40° F.	60° F.	80° F.	100° F.	120° F.	140° F.	160° F.	180° F.
$2.00	$85.54	$78.79	$68.80	$58.48	$47.07	$36.10	$24.50	$12.25
$2.50	110.82	98.42	86.03	73.23	58.90	45.12	30.70	16.25
$3.00	132.99	118.11	103.23	87.87	76.68	54.15	36.84	19.50
$3.50	155.15	137.80	120.44	102.52	82.46	63.17	42.98	22.75
$4.00	177.32	157.48	137.64	117.16	94.24	72.20	49.12	26.00
$4.50	199.48	177.16	154.85	131.81	106.02	81.22	55.26	29.25
$5.00	221.65	196.85	172.05	146.45	117.80	90.25	61.40	32.50
$5.50	243.82	243.81	189.26	161.10	129.58	99.27	67.50	35.75
$6.00	265.98	265.98	206.46	175.74	141.36	108.30	73.68	39.00

ARRANGEMENT OF PLANT WHERE EXHAUST STEAM IS UTILIZED FOR HEATING WATER.

In figure 3 there is given a diagrammatic plan of a plant in which the heat in the exhaust steam is utilized in heating water for boiler feed, wash purposes, etc. The exhaust steam from the pump is discharged into the exhaust main, where it mingles with the exhaust from the engine. The exhaust from both the pump and the engine flows around the coils of the heater, and that portion which is not condensed in the heater is discharged to the air through the exhaust valve, which is adjusted to open and relieve the pressure in the heater when it has reached a predetermined amount. The greater portion of the exhaust steam, however, is condensed in the heater and is drained to the sewer, together with the oil which has been introduced into the live steam for the purpose of lubricating the cylinders of the pumps and engine. The water enters the heater near the bottom, flows upward through the coil tubes, and leaves the heater near the top. The heat given up by the exhaust steam is absorbed by the water in its transit through the heater. The supply pipes are connected as shown and are used for supplying the system with cold water, either from the city mains or from a deep-well pump. A well-designed plant similar to that illustrated in figure 3 is capable of converting approximately 4 per cent of the heat value of the fuel into mechanical energy. The various heat losses are approximately as follows:

BOILER LOSSES.

	Per cent.
Loss due to unconsumed particles of coal falling through grate	2
Loss due to incomplete combustion	2
Loss due to heat being carried away in stack gases	23
Radiation, and other losses	8
Total boiler losses	35

	B.t.u.	
Heat required to develop 1 horsepower hour (assuming 40 pounds of steam per horsepower hour, gauge pressure 80 pounds, feed-water 210° F.)	40,000	
Engine friction, 1 per cent	400	
Leakage, radiation, etc., 2 per cent	800	
Total	41,200	
Heat equivalent of 1 horsepower hour	2,545	Per cent.
Heat value of steam converted into useful work	$\frac{2,545\times100}{41,200}=6.2$	
		Per cent.
Heat in coal converted into useful work	$\frac{2,545\times0.65\times100}{41,200}=4.0$	

Of the total heat in steam (100 per cent) only 6.2 per cent is converted into useful work by the engine. In milk plants, creameries, and dairies, where heat under 212° F. is required to raise the

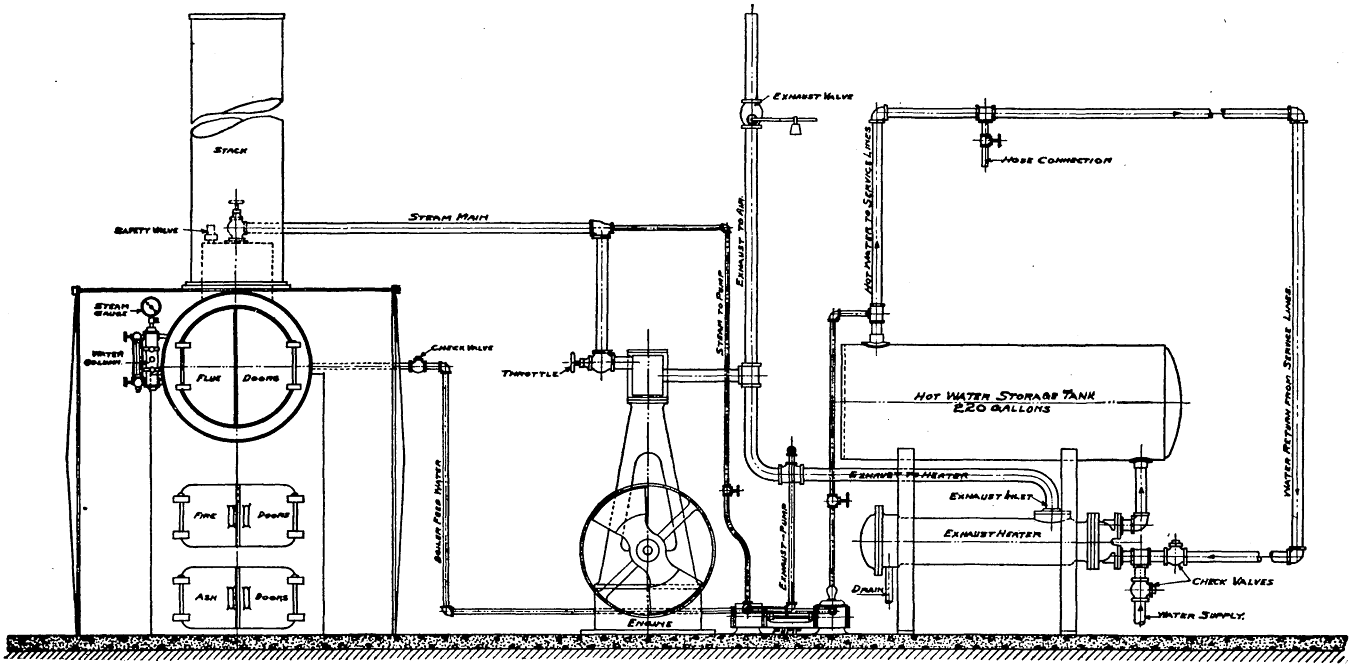

FIG. 3.—Plant equipped with water-heating apparatus.

temperature of milk before separating, and for heating skimmed milk, wash water, boiler feed water, the building, etc., it is possible to utilize the greater portion of this otherwise waste heat in the exhaust steam.

In the plant just described, suppose the engine is a 25 horsepower, using 40 pounds of steam per horsepower hour. In the average exhaust-steam feed-water heater 1 pound of steam in condensing gives up approximately 1,000 B. t. u. Allowing for radiation to the air, this will heat about 6 pounds of water from 60° F. to 200° F. Therefore, the total quantity of water per hour that the exhaust steam from the above-mentioned engine is capable of heating from an initial temperature of 60° F. to a final temperature of 200° F. is $\frac{25\times40\times1{,}000\times6}{1{,}000}=6{,}000$ pounds, or 723 gallons.

The hot-water heating system illustrated in figure 3 will cost approximately $275. This will include heater, storage tank, two check valves (one for water supply and one for hot-water return lines), and legs with tie bolts.

A water-heating equipment of this size is of sufficient capacity to furnish hot water for all needs in the majority of creameries. However, should a larger size be necessary, one with a 400-gallon capacity storage tank will cost approximately $350.

A CLOSED WATER HEATER NECESSARY.

Commercial water heaters for power-plant use are divided into two classes, namely, closed heaters and open heaters. In the closed heaters the water is usually circulated through metallic tubes while the exhaust steam is allowed to flow in and surround the tubes. The transmission of heat from the exhaust steam to the water is therefore through the metallic walls of the tubes. Closed heaters are sometimes spoken of as pressure heaters, due to the fact that they are usually installed in the feed line between the boiler feed pump and the boiler and are therefore subject to boiler pressure. In the open heaters the water is sprayed into an open chamber where it comes in direct contact with the exhaust steam, consequently the thermal efficiency of the open heater is slightly greater than that of the closed heater. The pressure carried in the open heater is, of course, that of the exhaust steam, which is about atmospheric pressure. The cylinder oil, however, in this type of heater is carried in and mixed with the water, whereas in the closed heater it is drained off with the condensed exhaust, which, in milk plants, creameries, and dairies, should be allowed to run to the sewer, since there is usually sufficient heat in the exhaust steam for all needs exclusive of the small amount contained in the condensed exhaust.

As absolute cleanliness is essential in milk plants, creameries, and dairies, it is not advisable to use the condensed exhaust for washing purposes, as the exhaust steam from the engine and pumps contains a considerable quantity of oil which has been introduced into the live steam for the purpose of lubricating the cylinders. It is impracticable to remove all traces of oil from the exhaust steam, even with the best oil separators. For ordinary purposes the exhaust steam may be sufficiently cleansed of oil, but when the condensed exhaust is to be used for washing dairy utensils, even a trace of oil may impart a flavor to the milk or cream, consequently an inclosed heater should be used.

THE SAVING EFFECTED WITH THE WATER-HEATING PLANT.

In a creamery making 500,000 pounds of butter annually it is estimated that a maximum of 1,000 gallons of hot water are used daily. It is customary to heat the wash water by live steam from the boiler. If this wash water is heated from an initial temperature of 60° F. to a final temperature of 212° F. the heat taken from the boiler is $1{,}000 \times 8.3\ (212-60) = 1{,}261{,}600$ B. t. u. Assuming that the boiler and setting have an efficiency of 50 per cent and that the coal burned has a heat value of 14,000 B. t. u. per pound, the quantity of coal required to heat the wash water will be $\frac{1{,}261{,}600}{14{,}000 \times .50} = 180$ pounds.

The average creamery of the above capacity is equipped with a 40-horsepower boiler which has a combined boiler and furnace efficiency of approximately 50 per cent. The boiler feed water is about 60° F. and the steam pressure about 80 pounds. If the plant is run 8 hours a day, 310 days in the year, the possible saving by using the equipment outlined in figure 3 is as follows:

	B. t. u.
Heating feed water from 60° to 212° F.$=40\times34.5\times8\ (212-60)=$	1, 678, 080
Heating wash water from 60° to 212° F.$=1{,}000\times8.3\ (212-60)=$	1, 261, 600
Total	2, 939, 680

If the coal has a heat value of 14,000 B. t. u. per pound the quantity saved will be $\frac{2{,}939{,}680}{14{,}000 \times .50} = 419.95$ pounds per day. If the coal costs \$4 per ton of 2,000 pounds the amount saved annually in money will be $\$4 \times \frac{419.95 \times 310}{2{,}000} = \$260.36$. Therefore the equipment will pay for itself in about 13 months.

A COSTLY ENGINE NOT ALWAYS ECONOMICAL.

Paradoxical as it may seem, it is not always the most economical plan to install a costly and complicated engine because of its smaller steam consumption. Where the generation of power is the prime

object, then, of course, an engine that will develop a horsepower on the least quantity of steam is desirable. But when there is use for the heat in the exhaust steam for heating buildings, boiler feed water, wash water, etc., the steam economy of the engine counts for little, and it is advisable to install a low-cost but durable engine, even though the steam required per horsepower hour is considerably greater.

By referring to the analysis of losses on a typical steam plant, given on page 7, it will be noted that the percentage of the heat value of steam converted into mechanical power is only 6.2, and adding to this the leakage and radiation losses from engine and piping we have a total of about 9 per cent, leaving the remainder in the exhaust available for heating purposes. Therefore, where there is use for all the exhaust steam from the engine and pumps, they become, from the standpoint of fuel consumption, merely pressure-reducing valves between the boiler and the heating system; consequently the mechanical power developed becomes, so to speak, a low-cost by-product of the heating system.

STEAM AND WATER PUMPS.

Where there is need for all the heat in the exhaust steam from the pumps and engine it is economy to install direct-acting steam pumps, although their steam consumption varies from 100 to 200 pounds per hour for each horsepower developed. By utilizing the heat in the exhaust for heating boiler feed water, all the heat which they do not convert into useful work, neglecting radiation, is returned to the boiler; consequently their efficiency is approximately 100 per cent. If, however, the engine exhaust is sufficient to provide for all heating, plunger pumps driven from an eccentric on the engine shaft, or by belt, are recommended, as the engine will produce a horsepower hour on about 40 pounds of steam, whereas if the pumps are operated by steam direct, from 100 to 200 pounds of steam will be required per horsepower hour.

In pumping hot water it is absolutely necessary to install the pump below the supply. If this is not done the pump will fail entirely or operate very unsatisfactorily, depending on the temperature of the water. In pumping cold water there is an atmospheric pressure on the surface of the water of 14.7 pounds per square inch, which will support a column of water approximately 30 feet high. Allowing for frictional resistance in the suction pipe and valves, if the pump is located within 20 feet above the supply it will operate satisfactorily, providing the piston speed of the pump is not too great to allow the water to follow up the piston.

The vapor pressure of water at 60° F. is only about one-quarter pound per square inch and is therefore negligible as compared with atmospheric pressure. With water at 212° F. the vapor pressure

is 14.7 pounds per square inch, or just equal to the atmospheric pressure, and if we try to lift water at this temperature by suction the body of water will not rise at all, but the steam vapor will rise from the surface of the water and follow the piston. With water at 200° F. there will be about 3.3 pounds pressure by the atmosphere in excess of the vapor pressure, which is sufficient to raise the water approximately 7.9 feet, but with no excess pressure to overcome the frictional resistance of the pipe and to lift the valves, to say nothing of giving velocity to the water.

The pump should be placed at least 3 feet below the supply when pumping hot water, in order that there may be sufficient head to force it through the supply pipe at the required velocity and to lift the valves in the pump chamber. The pump should be placed near the water supply, and the supply pipe should be as straight and free from bends as possible. The springs of the pump valves should be made as light as practicable to insure proper operation.

If, however, the pump is located at such a distance from the supply tank, or the supply pipe has so many abrupt bends that the head of 3 feet is not sufficient to force the required quantity of water through the supply pipe, the difficulty may be overcome by placing a standpipe in the supply pipe close to the pump. The standpipe may be vented to the air or back to the top of the supply tank. In either case the benefit of the full head will be obtained at the pump. To pump hot water successfully it is necessary to keep a solid body of water at all times against the pump plunger; otherwise the pump will not operate satisfactorily. The packing for a pump required to pump hot water should, of course, be adapted to the temperatures it will have to withstand.

INJECTORS.

By far the greater number of boilers in the type of plants under consideration are fed by injectors, and in view of the fact that the majority of the boilers are fed with cold water it is fortunate that injectors are used, inasmuch as the injector performs not only the function of a force pump but that of a heater as well, thereby protecting the boiler from the enormous strains which would be set up in the plates if cold water was fed directly to the boiler. While the injector has an efficiency of 100 per cent as an apparatus for boiler feed, it is nevertheless an uneconomical means, since it requires live steam from the boiler for its operation which would otherwise be consumed in useful work. It is impracticable to use feed water that has been previously heated by the waste heat in the exhaust steam from the engine and pumps when employing an injector, because it can handle only cold or moderately warm water, as its action depends on a feed-water temperature sufficiently low to condense the steam

in the injector at a rapid rate. Should the feed water be forced through a heater located between the injector and the boiler very little gain, if any, would be obtained, as the water from the injector will have about as high temperature as the exhaust steam; consequently it would absorb but little heat. Injectors are valuable, however, as an auxiliary means of feeding a boiler, to be used when the engine is not running or in case of a breakdown of the boiler feed pump.

As the available heat in the exhaust steam from the engine and auxiliaries is more than sufficient for heating the boiler feed water and wash water, the utilization of the remainder for heating the building, skimmed milk, starter milk, and for pasteurizing, etc., will be considered in a later circular.

Approved.

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *January 16, 1913.*

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